Conclusion and scope for the future work

In the present work samples have been synthesized by a novel microwave method and by ceramic method for the studies of V-I characteristics and for shielding the noise generated due to electromagnetic interference. High field electrical switching behaviour of the following glasses has been synthesized by a novel microwave method:

I. Glasses synthesized for electrical switching using microwave method:
   i) $xNa_2SO_4:y[0.8NaPO_3 + 0.2MoO_3]$ where $x=5,10,15,20$ and $25$; $y=100-x$; MNP glass system.
   ii) $xNa_2SO_4:y[0.8NaPO_3 + 0.2V_2O_5]$ where $x=5, 10, 15, 20$ and $25$; $y=100-x$; NPV glass system.
   iii) $xV_2O_5.20Li_2O.(80-x)[yB_2O_3+z ZnO]$ where $10 \leq x \leq 50$ and $(y/z) = 1.2$; VZB glass system.
   iv) $xMoO_3:10Li_2O: (90-x) P_2O_5$ where $40 \leq x \leq 80$; MLP glass system.

II. The samples prepared for study of electromagnetic interference shielding using conventional ceramic method.

$$Li_{0.3-x/4}Zn_{0.5-x/2}Ni_xMn_{0.1}F_{2.15-x/4}O_4$$

where $x=0.1$ to $0.3$ in the step of $0.1$, have been prepared.

Based on the results obtained through various characterizations viz. X-ray diffraction, Vickers hardness, modulated DSC, dc conductivity, impedance measurements, EPR study, SEM and shielding effectiveness using network analyzer. The following conclusions are drawn:
The amorphous nature of the samples was tested by using X-Ray powder diffractometer and all the investigated samples exhibited only a broad hump like feature in the low angle region, characteristic of glassy nature.

DSC thermograms are used to extract the glass transition temperature $T_g$ and width of glass transition $\Delta T_g$. The procedure used to extract $T_g$ and $\Delta T_g = T_l - T_g$ where $T_l$ is the liquidus temperature.

Density ($\rho$), Vickers hardness ($H_v$), structural rigidity and $T_g$ decreases with increasing concentration of Na$_2$SO$_4$.

It is also evident that fragility function $(F) \propto \Delta T^{-1}$, $\Delta T^{-1}$ increases [31] with Na$_2$SO$_4$ concentration, indicating the fact that the dissolution of SO$_4^{2-}$ make the investigated glass more fragile and less rigid.

The electrical Switching behavior of MNP, NPV, VZB and MLP glass systems have been carried out in a wide range of composition. MNP and NPV glasses have not been switched even when the thickness of the glass sample varied from 0.15 mm to 0.3mm. Surprisingly in VZB glasses only VZB4 and VZB5 glasses exhibited switching while VZB1, VZB2 and VZB3 glasses did not show any switching. In the case of VZB4 glasses switching is seen for $d=0.15$mm and 0.20mm while in VZB5 glasses switching is observed for $d = 0.15 – 0.3$mm. Further, the temperature dependence of electrical switching is studied over a temperature range 300K to 333K.

The variations seen in threshold voltages with thickness, composition and temperature reveal the following: a) Switching strongly depends on the composition, b) Switching depends on the thickness of the sample and c) Switching depends on the thermal conditions of the sample.
From the switching measurements we made an hypothesis that increasing the content of the transition metal oxide ($V_2O_5$ and $MoO_3$) have a considerable impact on switching behaviour. Therefore, we prepared MLP glass with high transition metal oxide (TMO) concentration (from 40 to 80 mol %). All the synthesized glasses were showed switching behaviour at ambient temperature and also exhibited temperature dependence.

In all the glass compositions with sodium sulphate, dc conductivity increases with increasing concentration of $Na_2SO_4$ and temperature.

The complex impedance have real and imaginary parts which contain information on the kinetics of electrical relaxation in bulk glassy material $Z'$ shows a dip prior to merge at high frequency and decrease with increasing temperature. Whereas $Z''$ values increases with log (f) reaches a maximum and the peak ($Z''_{max}$) shifts to higher frequencies with increasing temperature. Besides, the asymmetric nature of $Z''$ with log (f) suggests a spread in relaxation process.

In order to examine the changes seen in $\sigma$ (conductivity) and $E_{dc}$ of $Na_2O$ modified molybdo-phosphate glasses, in which sodium sulphate is dissolved. The effect of network modification reveals the nature and concentration of structural motifs present in the glass network.

The d.c conductivity increases while the activation barrier for ion transport decreases with increasing concentration of $Na_2SO_4$.

The variation seen in the $\sigma_{dc}$ and $E_{dc}$ explained on the basis of a simple structural model along with the concentration of $Na^+$ and $SO_4^{2-}$ ions.
The ac conductivity behaviour of the investigated glasses is explained using Almond-West type of power law and the power law.

The increase in dielectric constant with temperature is attributed to the effect of dipolar polarization, inter-molecular forces, orientation vibrations and thermal agitations. The polarizabilities contribution from ionic and orientation sources decrease at higher frequencies and disappear due to inertia of the ions.

Complex electrical modulus varies with frequency, the M'' \text{max} of asymmetric peak shifts towards higher frequencies as a function of temperature. Frequency corresponding to M'' \text{max} will always satisfy the condition \( \omega_o = \frac{1}{\tau_c} \) where \( \tau_c \) is the most probable conductivity for relaxation time. The temperature dependence of conductivity relaxation follows the Arrhenius relation.

The activation energy is calculated by least square fits compares well with the activation energies for dc conductivity.

In order to elucidate the conductivity mechanisms operating in the investigated glasses scaling has been done in both conductivity and relaxation as a function of reduced frequency. Scaling reveals that the dynamic process is temperature independent and a single ion transport mechanism is operating in the investigated glasses.

Vanadium pentoxide doped with lithium zinc borate glasses were prepared by a microwave showed a different trend. The following are the important inferences drawn:

i) \( T_g \)-values decreases with increasing \( V_2O_5 \) concentration, which is attributed to bond energies and the alterations occur in the network linkages.
ii) The investigated glasses exhibited $\Delta T_g < 30$, hence they are fragile.

iii) The conduction mechanisms operating in these glasses were analyzed by impedance spectroscopy and EPR studies.

iv) At $V_2O_5=10$ mol%, glasses exhibited ion conduction.

v) At $V_2O_5=20$ mol%, there is a transition between predominantly electronic and predominantly ionic conduction.

vi) At $V_2O_5=30-50$ mol%, glasses exhibiting electronic conductivity and the conduction was explained on the basis of Mott’s polaronic theory.

vii) EPR studies confirms that the glasses with least $V_2O_5$ content exhibited hyperfine spectra, which confirms the presence of less number of vanadium sites, leading to conduction. The glasses with $x \geq 30$ hyperfine structure is absent duet to the overlapping of absorption signals confirms the electronic conductivity due to the transfer of electrons in a aliovalent vanadium sites.

- The samples for measuring shielding effectiveness were prepared by ceramic method.

- XRD measurements confirm characteristic peaks.

- The surface morphology of the samples was analyzed with the help of SEM images obtained at different temperatures and is found that the grain size of the sample surface varies drastically.

- Dielectric measurements were carried out and are found that the dielectric constant decrease with increase in temperature, also loss tangent was calculated.

- Shielding effectiveness of the sample was calculated for different frequencies and is found be maximum at 4GHz, which is in good agreement with theoretical value.
Scope for the future work

Oxide glasses containing transition metal ions are semiconducting and exhibit nonlinear electrical properties. Hence they find potential technological applications. Further studies on microwave prepared glasses with different transition metal ions can be checked for memory/threshold switching behavior. Switching phenomenon in semiconducting glasses find applications in information storage, power controlled devices etc. Impedance and electrical conductivity studies on glasses containing sulphate ions are very interesting and the conductivity is enhanced due to the presence of sulphate ions in the glass matrix. Further investigations may yield materials suitable for sodium ion battery applications.

In view of recent advances of nano-technology, the possibility of synthesizing nano-particle ferrites at lower sintering temperatures could be investigated. Since very few researchers have carried out the switching behaviour in nano-composites. Further investigations in this direction may find applications in memory devices. Materials exhibiting shielding of electromagnetic noise due to interference find a potential applications in mobile and satellite communication. Nano-ferrites mixed with grapheme could be studied for further improvement in the suppression of noise.